Early Tertiary Exhumation of the Flank of a Forearc Basin, Southwest Talkeetna Mountains, Alaska

Map showing location and age by U-Pb zircon SHRIMP (red) and

detrital zircon youngest population (orange)

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1U.S. Geological Survey ²Apatite to Zircon, Inc. 3U.S. Geological Survey and Stanford SHRIMP

DISCUSSION

New geochronologic and thermochronologic data from rocks near Hatcher Pass, southwest Talkeetna Mountains, Alaska, record earliest Paleocene erosional and structural exhumation on the flank of the active Cook Inlet forearc basin. Cretaceous plutons shed sediments to the south, forming the Paleocene Arkose Ridge Formation. A Paleocene(?)-Eocene detachment fault juxtaposed ~60 Ma metamorphic rocks with the base of the Arkose Ridge Formation.

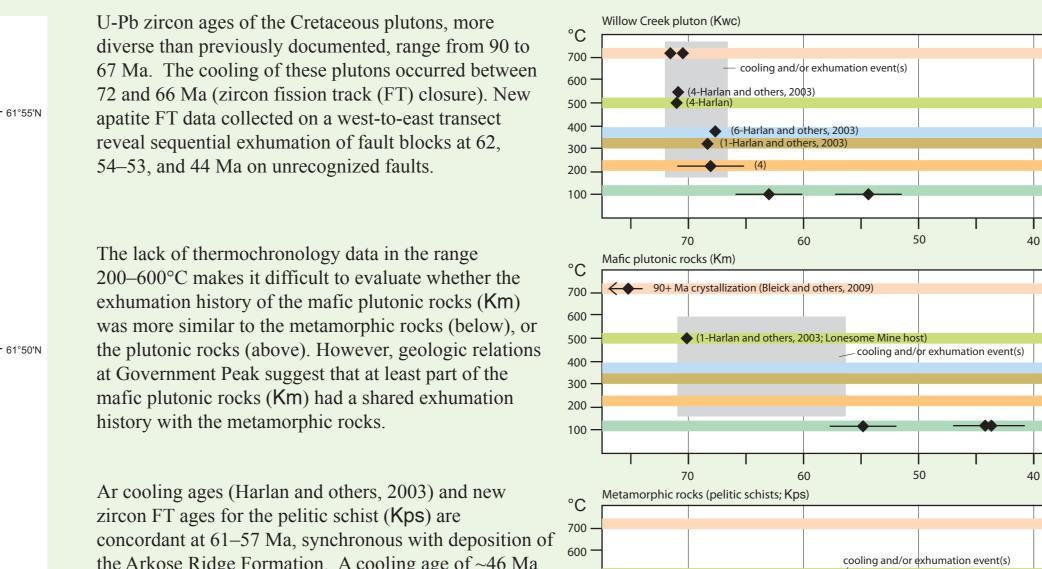
U-Pb (analyzed by Sensitive High Resolution Ion Micro Probe Reverse Geometry (SHRIMP-RG)) zircon ages of the Cretaceous plutons, more diverse than previously documented, are 90.3 ± 0.3 (previously considered a Jurassic unit), 79.1 ± 1.0 , 76.1±0.9, 75.8±0.7, 72.5±0.4, 71.9±0.3, 70.5±0.2, and 67.3±0.2 Ma. The cooling of these plutons occurred between 72 and 66 Ma (zircon fission track (FT) closure ~225°C). ⁴⁰Ar/³⁹Ar analyses of hornblende, white mica, and biotite fall into this range (Harlan and others, 2003). New apatite FT data collected on a west-to-east transect reveal sequential exhumation of fault blocks at 62.8±2.9, 54±2.5, 52.6±2.8, and 44.4±2.2 Ma.

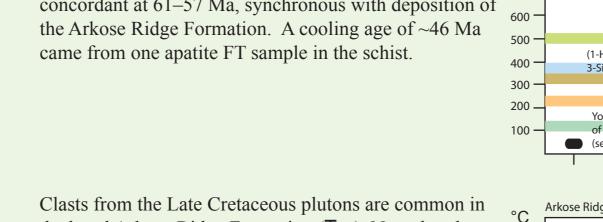
Plutonic clasts accumulated in the Paleocene Arkose Ridge Formation to the south. Detrital zircon (DZ) ages from the formation reflect this provenance: a new sample yielded one grain at 61 Ma, a dominant peak at 76 Ma, and minor peaks at 70, 80, 88, and 92 Ma. The oldest zircon is 181 Ma. Our apatite FT ages range from 35.1 to 50.9 Ma.

Greenschist facies rocks now sit structurally between the plutonic rocks and the Arkose Ridge Formation. They are separated from plutonic rocks by the vertical Hatcher Pass fault and from the sedimentary rocks by a detachment fault. Ar cooling ages (Harlan and others, 2003) and new zircon FT ages for these rocks are concordant at 61–57 Ma, synchronous with deposition of the Arkose Ridge Formation. A cooling age of ~46 Ma came from one apatite FT sample. The metamorphic protolith (previously considered Jurassic) was deposited at or after 75 Ma based on new DZ data. The probability curve has a major peak from 76 to 102 Ma, minor peaks at 186, 197, 213, 303, 346, and 1,828 and two discordant grains at ~2,700 Ma. This is similar to DZ populations in the Valdez Group. The short period of time between deposition, metamorphism, and exhumation are consistent with metamorphism in a subduction-zone setting. Ductile and brittle structures in the metamorphic rocks are consistent with exhumation in a transtensional setting.

GEOLOGIC MAP

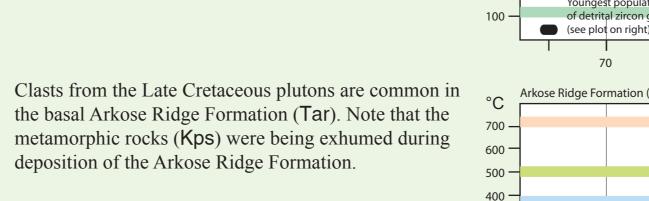
THERMOCHRONOLOGY





⁴⁰Ar/³⁹Ar White Mica

Mortensen data published in Harlan and others, 2003

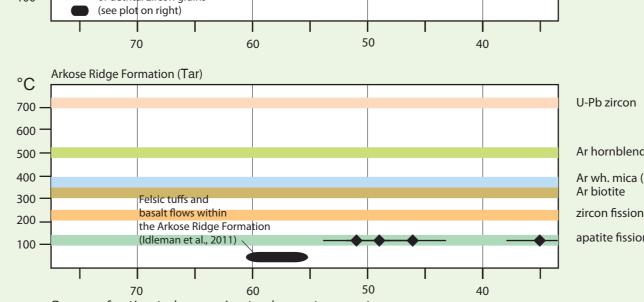


Plutonic Rocks

72.8-70.5 Ma

66.9–65.6 Ma

70–67.9 Ma



Source of estimated approximate closure temperatures: Reiners and others, 2005 (U-Pb zircon, Ar-muscovite, zircon, and apatite fission track) prospect near Iliamna.

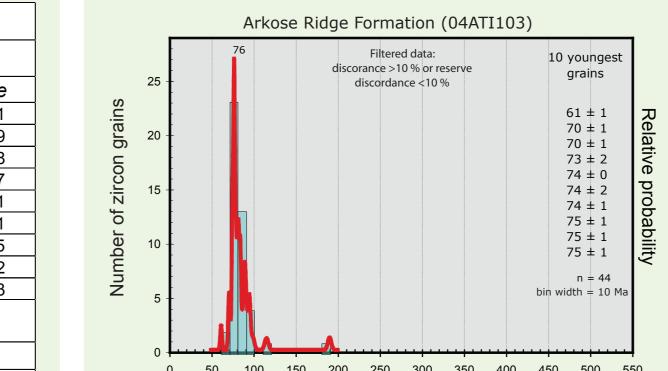
Data from Harlan and others, 2003

Source

Data from Harlan and others, 2003

Data from Harlan and others, 2003

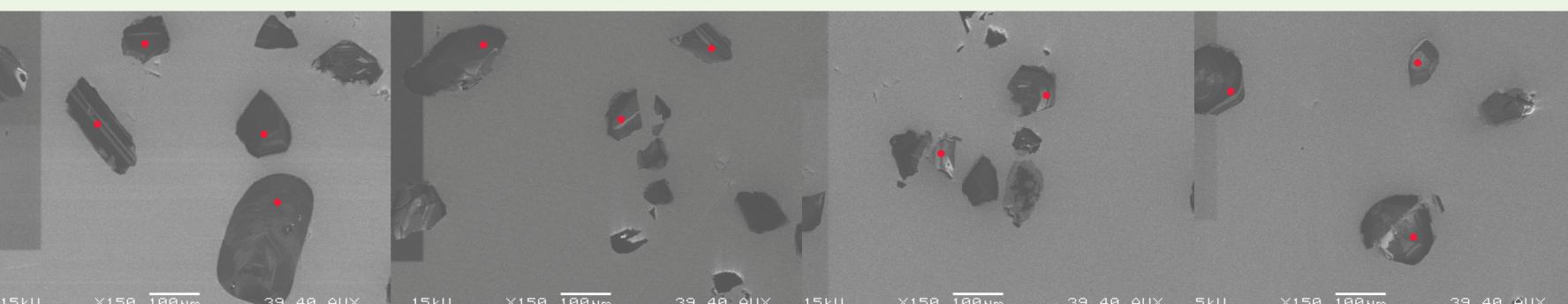
Data from Harlan and others, 2003



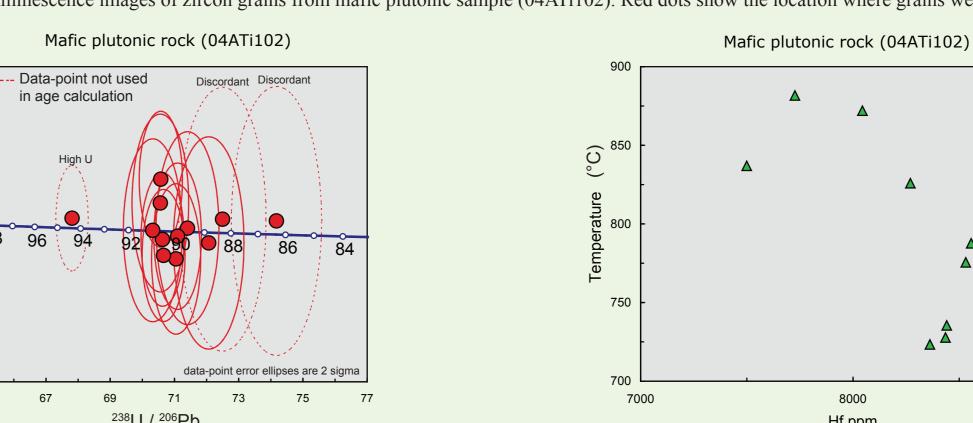
206_{Pb/} 238_U age (Ma) accumulated in the Paleocene Arkose Ridge Formation. Detrital zircon (DZ) ages from the formation reflect this provenance: new sample yielded one grain at 61 Ma, a dominant peak at 76, and minor peaks at 70, 80, 88, and 92 Ma. The oldest zircon is 181 Ma.

90 Ma MAFIC PLUTONIC ROCKS (Km)

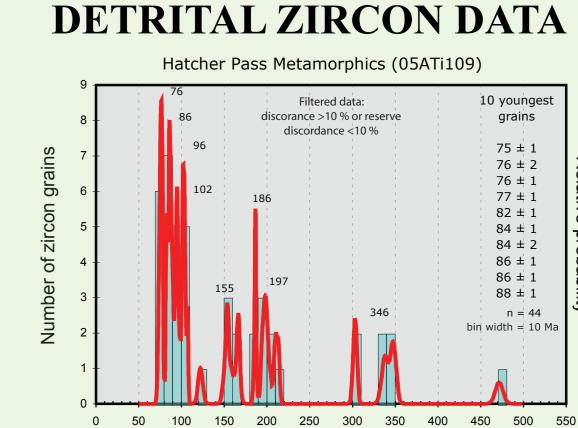
U-Pb DATA



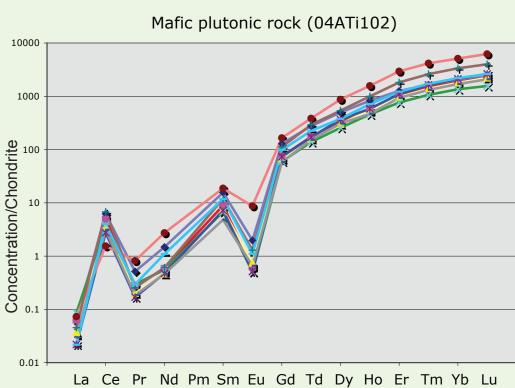
Cathodoluminescence images of zircon grains from mafic plutonic sample (04ATi102). Red dots show the location where grains were analysed using the SHRIMP-RG.



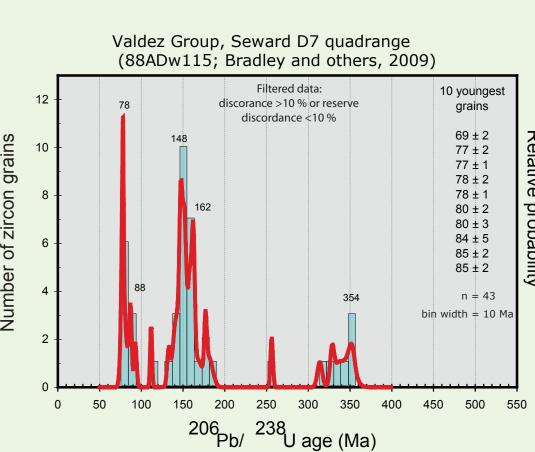
Tera-Wasserburg concordia plot of the new SHRIMP-RG date of Crystallization thermometry for zircons in the mafic plutonic $90.3\pm0.3 \text{ Ma (n} = 9 \text{ average } ^{206}\text{Pb} / ^{238}\text{U age) from a mafic}$ rocks (Km) using SHRIMP-RG techniques of Watson and plutonic rock (Km) that was previously thought to be Jurassic. others (2006). The zircons returned temperatures broadly This is the age of the supergiant Pebble Copper porphyry consistent with major-phase thermometry at 725°C to 875°C.



206_{Pb/} 238_U age (Ma) Detrital zircon data illustrated here are from a sample of pelitic schis collected from unit Kps. The metamorphic protolith, based on these DZ data, was deposited at or after about 76 Ma. The probability curve has major peaks from 76 to 102 Ma, minor peaks at 155, 186, 197, 213, 303, 346, 1,828 and two discordant grains ~2,700 Ma. The unit was previously considered Jurassic.

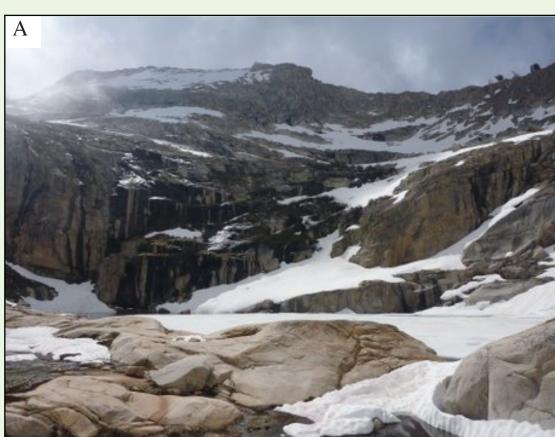


Rare earth-element for zircons in the mafic plutonic rocks (Km) using SHRIMP-RG techniques. Zircon signatures from Km could be used to compare similarly aged 90 Ma plutons.



curve for the pelitic schist at Hatcher Pass (Kps).

PHOTOGRAPHS





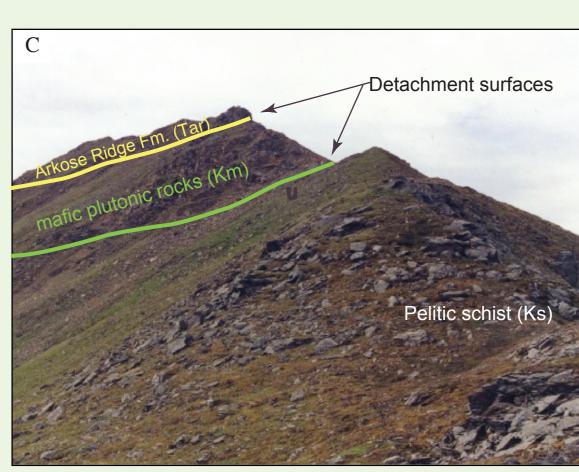
below Government Peak.



Zircons from this unfoliated outcrop of the mafic plutonic rock unit (Km) provided 90.3±0.3 Ma age using the SHRIMP-RG. The outcrop is located on a ridge on the northeat flank of Government Peak (map no. 5 on map). The rock is composed of plagioclase felspar and hornblende.



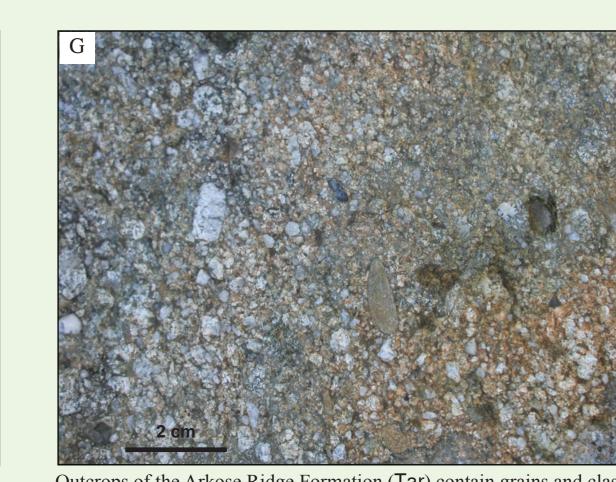
Outcrop of pelitic schist (Kps) with lens-shaped quartz pods elongate within the



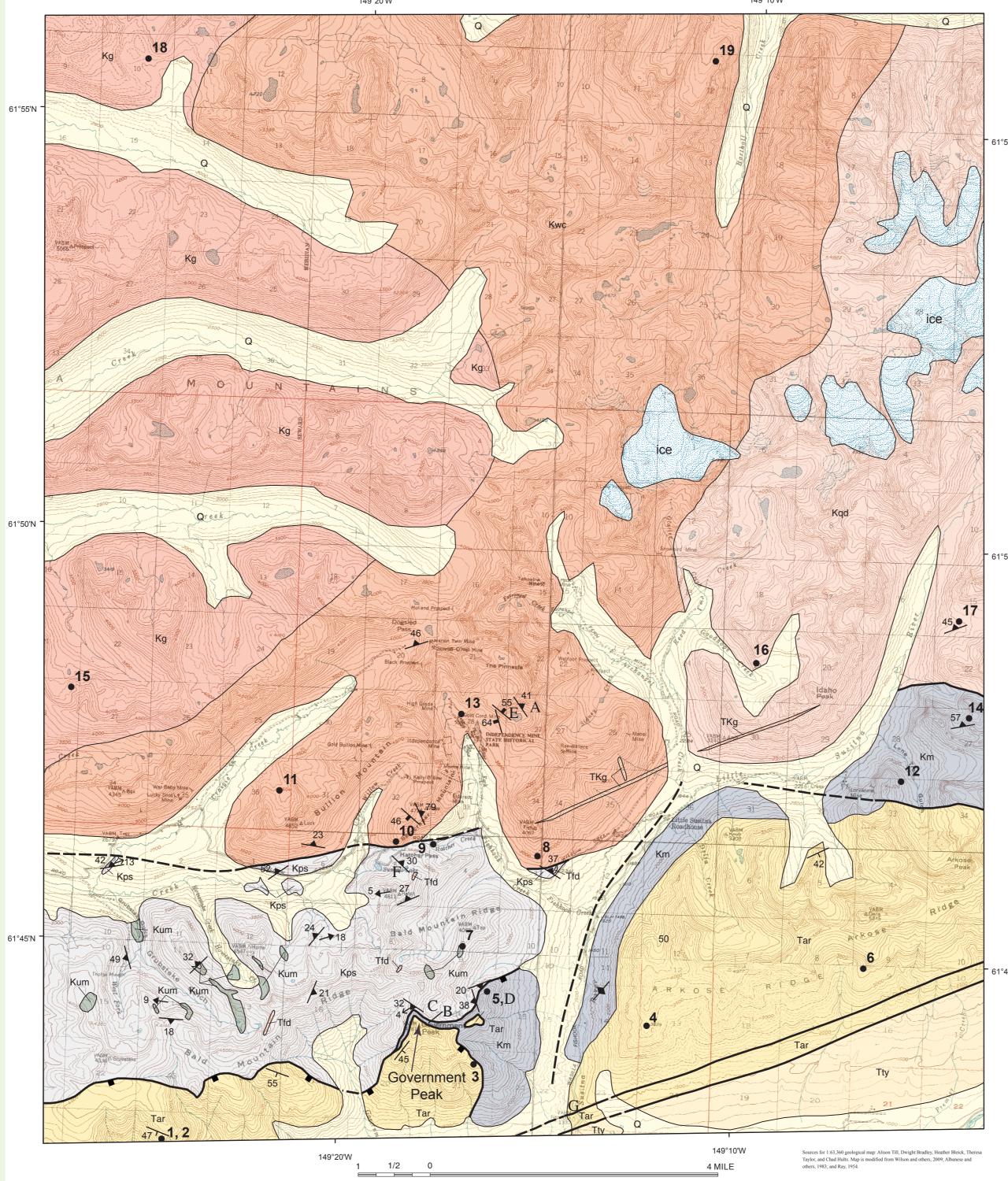
sit between the Paleocene Arkose Ridge Formation (Tar) and the 60-Ma greenschist-facies metamorphic rocks (Kps). Photo looking south-southeast along ridge that extends north from Government Peak



bitiote, and hornblende. Several of the plutons contain small igneous enclaves that are typically finer grained.



Outcrops of the Arkose Ridge Formation (Tar) contain grains and clasts of plagioclase and the quartz-rich plutonic rocks.



CONTOUR INTERVAL 100 FEET NATIONAL GEODETIC VERTICAL DATUM OF 1929 **DESCRIPTION OF MAP UNITS** serpentinite), and chlorite-plagioclase rock. Foliation is mylonitic (quartz ribbons, broken SURFICIAL DEPOSITS feldspars) near unit contacts and at some localities within the unit. Protolith age is Surficial deposits, undivided (Quaternary) Cretaceous and schist was metamorphosed in the

Tertiary (Harlan and others, 2003) SEDIMENTARY ROCKS Kum Ultramafic and mafic rocks (Cretaceous)—Lenses **Tyonek Formation (Miocene and** of green- and orange-weathering metamor-Oligocene?)—Sandstone, siltstone, phosed mafic and ultramafic rocks conglomerate, and claystone Arkose Ridge Formation (Eocene and **IGNEOUS ROCKS Paleocene?**)—Sandstone, siltstone, and Gossan (Cretaceous and Tertiary?)—Intensely oxidized and weathered red stained, iron oxides METAMORPHIC ROCKS Quartz Diorite (Cretaceous)—Dominated by Dikes (Tertiary?)—Very fine grained porphyritic plagioclase, quartz, biotite, and hornblende to equigranular felsic dikes, commonly

altered: felted fine-grained plagioclase,

sericite, quartz, calcite, iron oxide; locally

contains fine plagioclase or hornblende quartz, biotite, hornblende, and sphene Quartz Diorite in the east (Cretaceous?)— Pelitic schist (Cretaceous)—Pelitic and Dominated by plagioclase, quartz, biotite, and hornblende with increase in mafic enclaves and semipelitic schist, chlorite and locally garnet bearing; plagioclase porphyroblasts are contains orbicular quartz diorite common. Contains volumetrically minor Mafic plutonic rocks (Cretaceous) meters-thick foliation-parallel layers of mafic Predominantly massive and layered varieties of (actinolite-chlorite-plagioclase-epidote), hornblende gabbro, with lesser clinopyroxenite; ultramafic (tremolite ± chlorite ± talc ± locally cut by layers and veins of pale dioritic or serpentine), ophicarbonate (talc - dolomite quartz dioritic material

Quartz Diorite of the Willow Creek pluton

(Cretaceous)—Dominated by plagioclase,

Map showing location and cooling age of 40 Ar/39 Ar hornblende

Map showing location and cooling age by zircon fission track (black) and apatite fission track (brown).

MAP SYMBOL EXPLANATION

Age control location—Map number listed in table

→ Bearing and plunge of fold axes in metamorphic rocks

Strike and dip of bedding in sedimentary rocks

25 Strike and dip of joints in igneous rocks

 \rightarrow^{10} Stretching lineation in metamorphic rocks

—— Contact—Depositional, intrusive, or metamorphic

——— Fault—Dashed where thought to be present in subsurface

Detachment fault—Extensional; box on upper plate

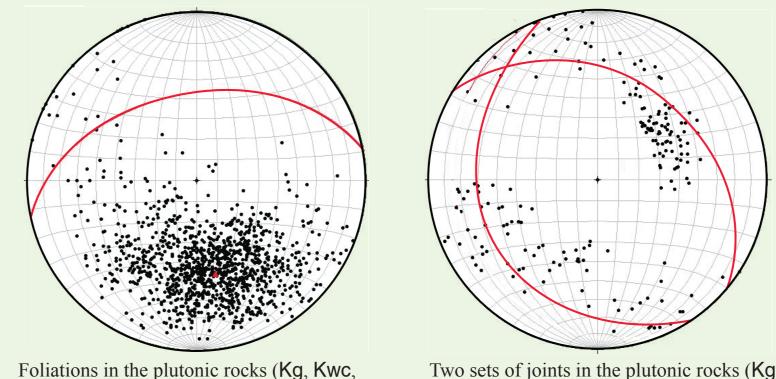
A Photograph location

Strike and dip of foliation

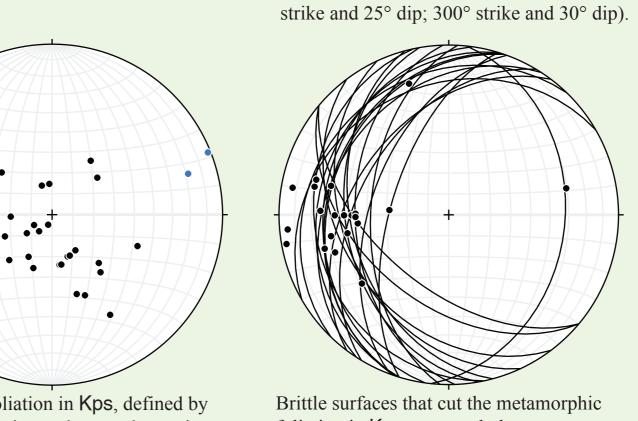
→ Strike of vertical foliation

(green), ⁴⁰Ar/³⁹Ar biotite (blue) and ⁴⁰Ar/³⁹Ar white mica (purple) **Apatite Fission Track (AFT)** Metamorphic Rocks (analytical method described in Bradley and others, 2009) ⁴⁰Ar/³⁹Ar White Mica Source ⁴⁰Ar/³⁹Ar White Mica Harlan and others, 2003 61–57 Ma ⁴⁰Ar/³⁹Ar White Mica Harlan and others, 2003 Zircon Fission Track (ZFT) Apatite Fission Track (AFT) 9 Kps Fission Track Apatite Arkose Ridge Formation Detrital Zircon (DZ) Apatite Fission Track (AFT) 6 Tar Fission Track 3 Tar Fission Track

EQUAL-AREA STEREONETS



Foliations in the plutonic rocks (Kg, Kwc, and Kqd) are defined by feldspars, biotite, and hornblende (majority of measurements from Ray, 1954). Black symbols are poles to foliation (n = 736). Red symbols show the mean value (259° strike and 47° dip).



Metamorphic foliation in Kps, defined by white mica, chlorite, and quartz lenses is gently folded around east-northeast and west-southwest axes. Black are poles of foliation (n = 28) and blue are fold axes measured (n = 9).

Brittle surfaces that cut the metamorphic foliation in Kps commonly have approximately east-west oriented slickensides. Movement on the brittle surfaces is normal (down-dip). Black great circles are slick surfaces measurements (n =

21). Black points are slick lineations (n = 2

Kwc, and Kqd) record brittle deformation in latest Cretaceous plutonic rocks (majority of

symbols are poles to joints (n = 178). Red

symbols show the mean of joint sets (147°

measurements from Ray, 1954). Black

CONCLUSIONS

New dates on the plutonic rocks show that they are more diverse in age than previously thought:

New SHRIMP-RG data show that the mafic plutonic rocks (Km), previously thought to be part of the Jurassic Talkeetna Arc, are in fact Cretaceous (90.3±0.3 Ma). The relation of the mafic plutonic rocks to the Talkeetna Arc is unknown.

New SHRIMP-RG data show that there are a number of unrecognized plutonic bodies north of Hatcher Pass with ages that vary from 79 to 67 Ma.

The pelitic schist (Kps) and the mafic intrusive rocks (Km) were exhumed during the Tertiary along a detachment fault now exposed at Government Peak and along related structures.

Ductile (east-west stretching lineations, not shown in stereonets) and brittle structures (slickenlines) in the metamorphic rocks (Kps) are consistent with east-west elongation of the unit during exhumation, possibly in a transfensional tectonic setting.

We postulate that the schist of Hatcher Pass may represent metamorphosed Valdez Group that was subducted and then exhumed during the Paleogene.

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